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INT CL[5] G05B 19/00 19/02 19/04, G05D 16/20
Online database: WPI

(54) Gas supply pressure control apparatus

(57) The pressure of gas in a gas main 10 is controlled according to one of a number of pressure profiles stored in electric controller 28, to provide an appropriate pressure for the time of day, day of the week, season of the year etc. Electrically operated valves 56, 58 place a command value on line 29 representing the current desired profile pressure. Pilot governor 18 regulates the flow in auxiliary gas line 12 accordingly, which in turn, through inspirator 20 controls the pressure in the main gas line 10. A feedback pressure in line 11 also acts on pilot governor 18. The electronic system monitors, at 13 and 15, the upstream and downstream pressures for data logging, to monitor adherence to the pressure profile, to update the shape of the pressure profiles and to switch from one profile to another if certain criteria are met.

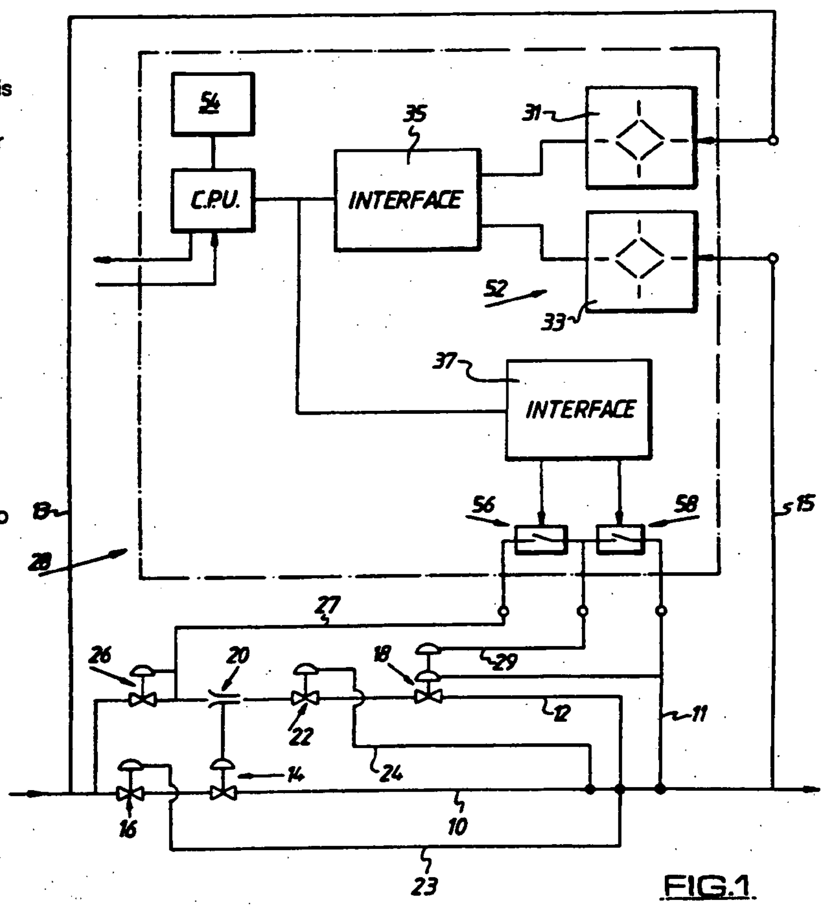

FIG.1

At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

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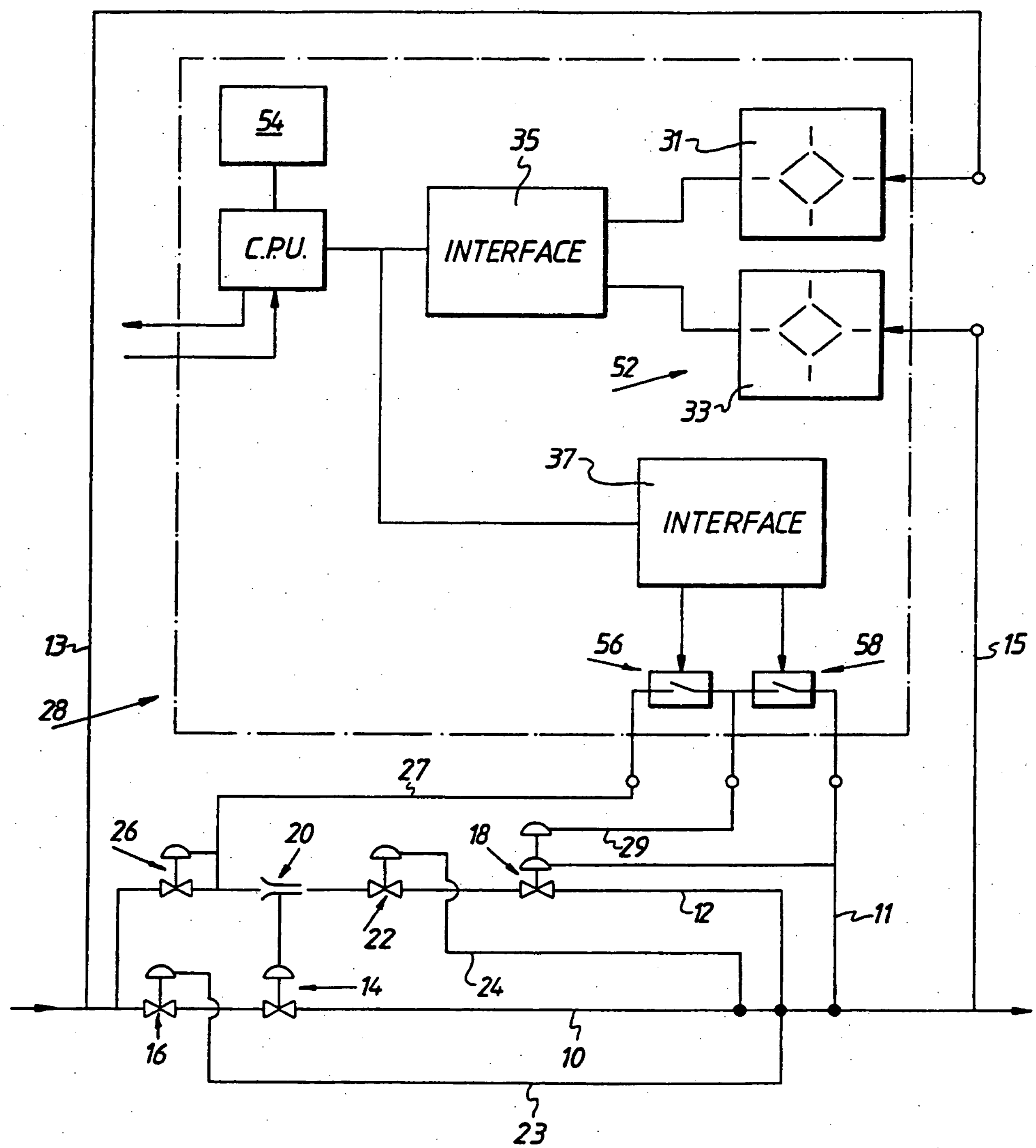
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FIG.1

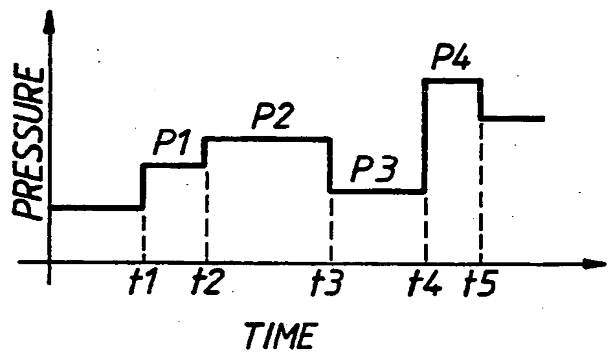


FIG.2

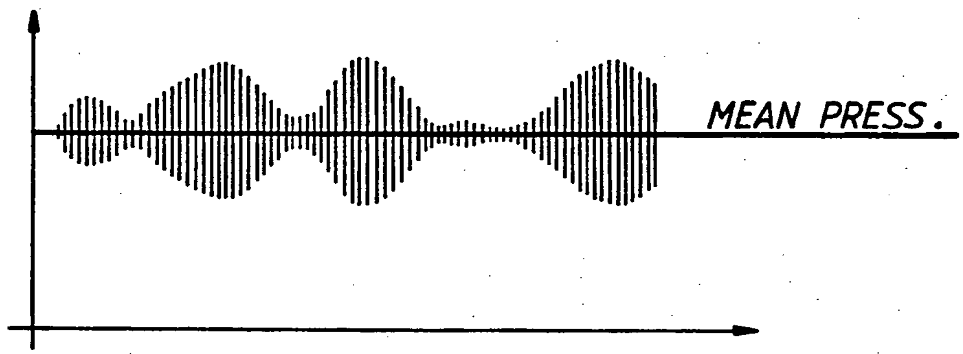


FIG.3

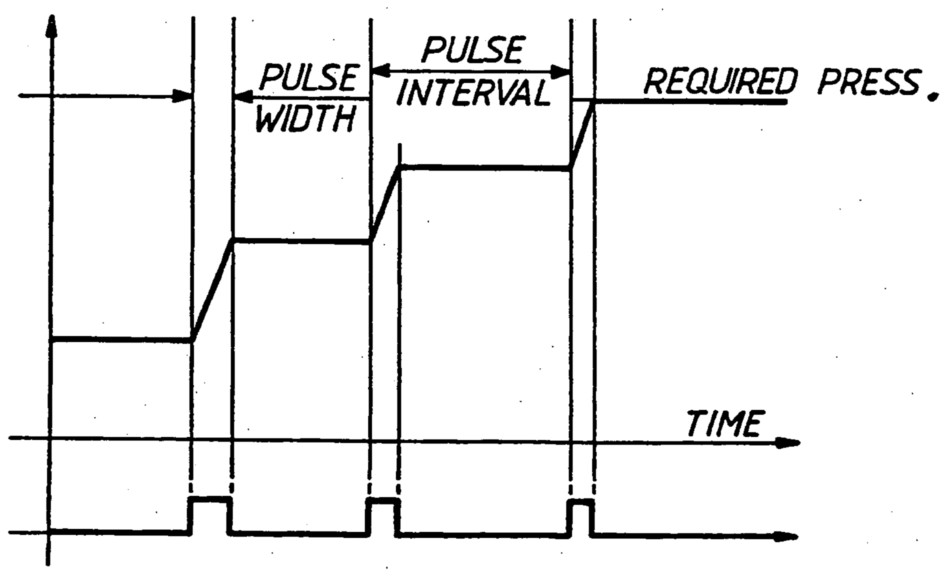
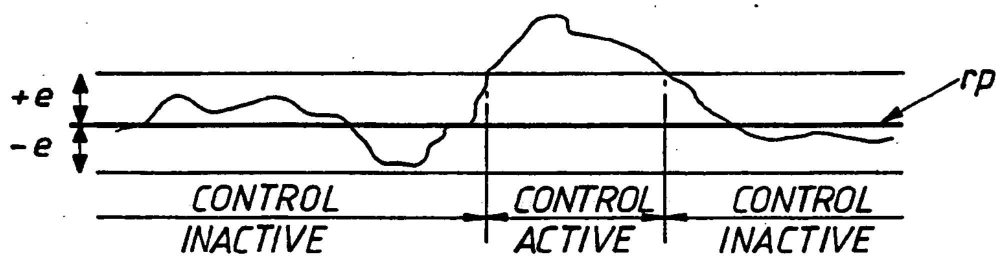


FIG.4


+e
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rp
CONTROL
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CONTROL
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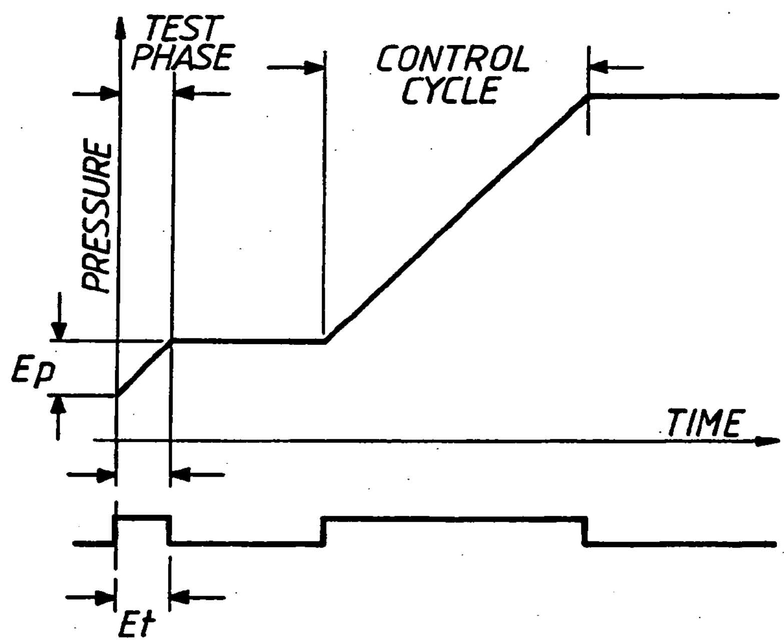
CONTROL
INACTIVE

FIG.5


TEST
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PRESSURE
Ep
TIME
Et

FIG.6

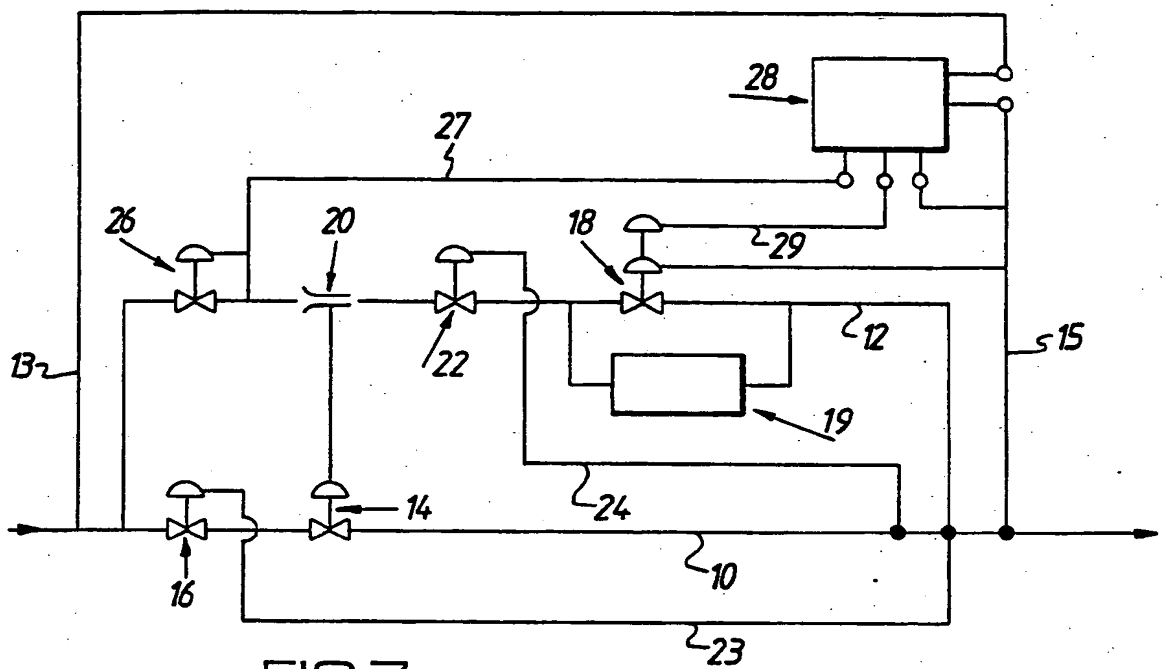

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FIG.7

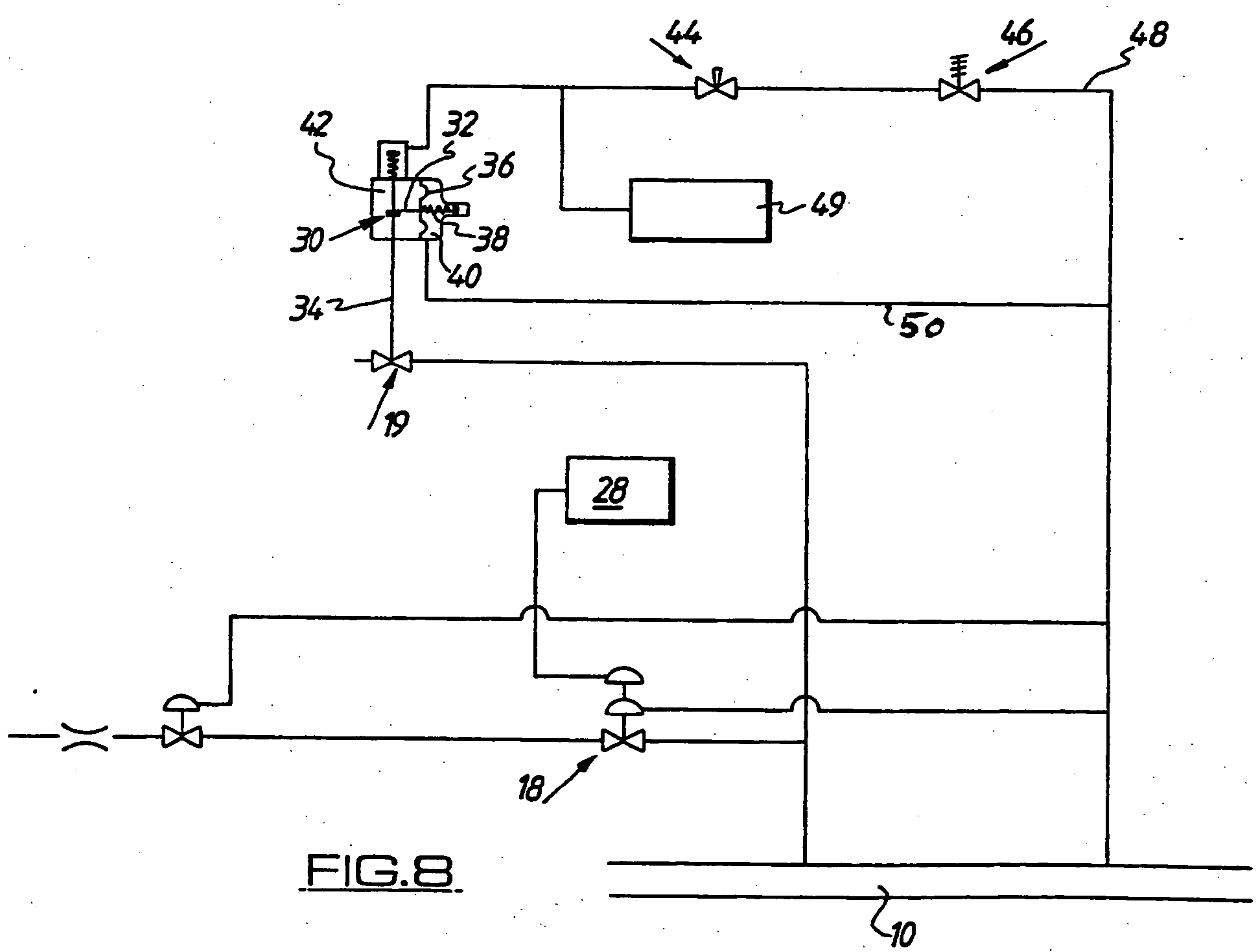

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FIG.8

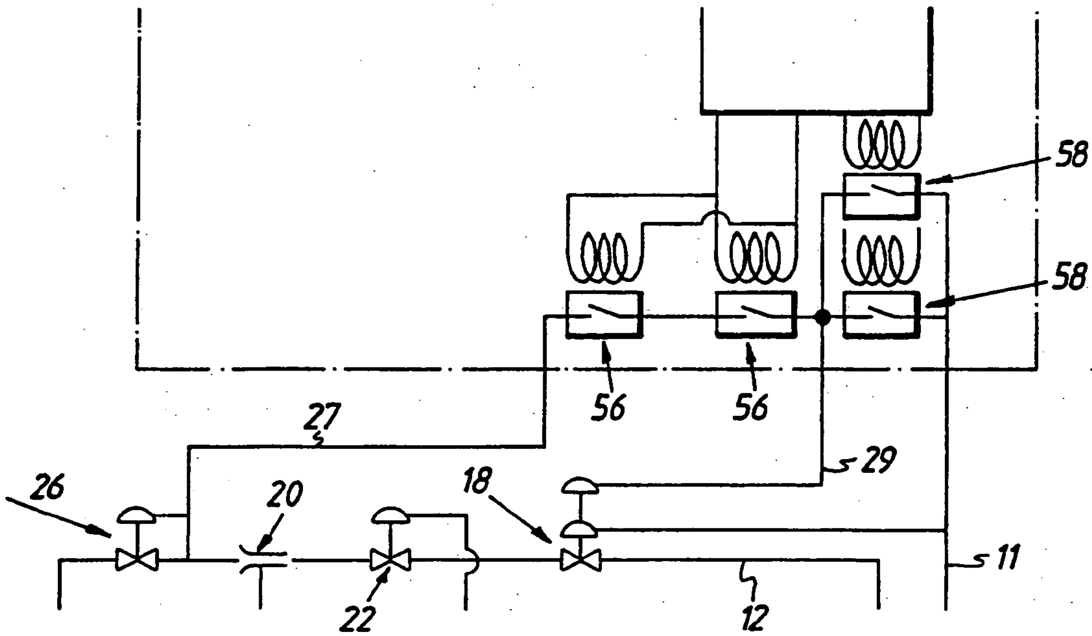
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FIG.9

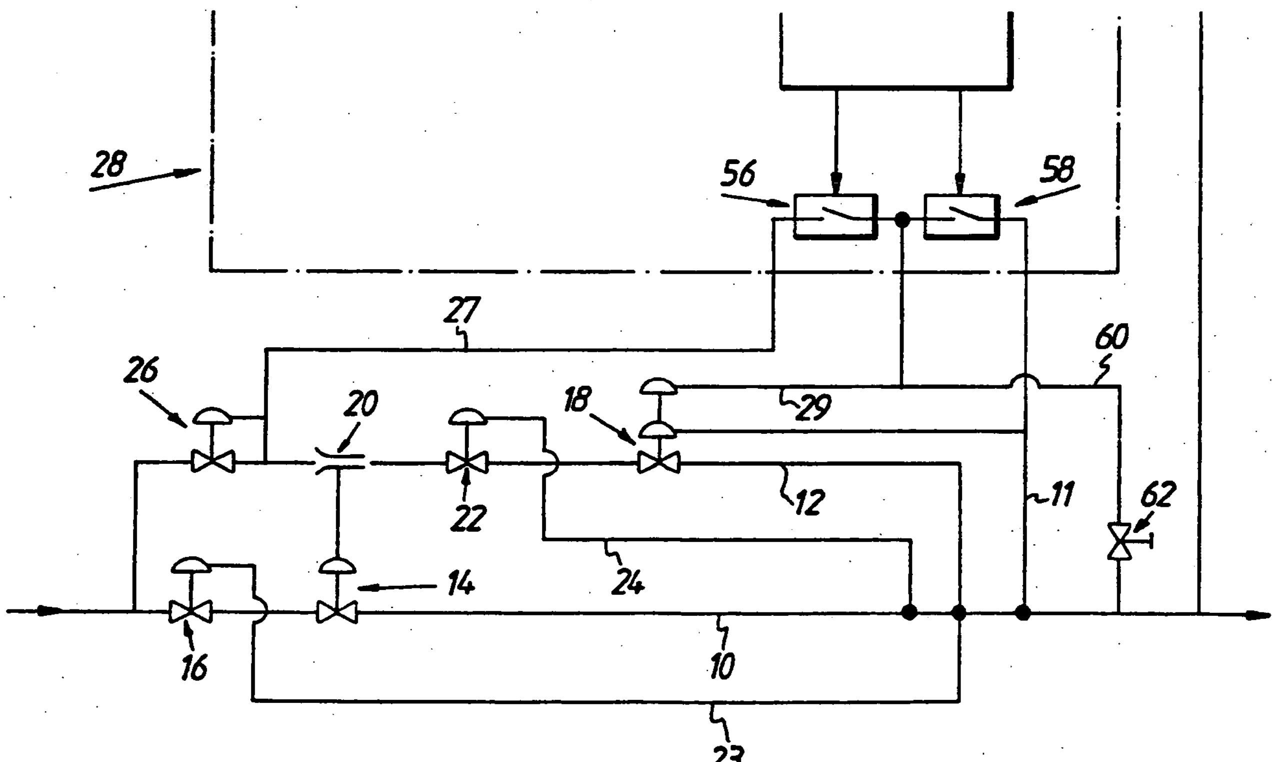
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FIG.10

Gas supply pressure control apparatus.

The invention relates to gas supply pressure control apparatus.

In all gas distribution networks, for the sake of safety there is a requirement that the supply pressure must not at any time fall below a statutory minimum value. However, there is invariably a considerable fluctuation in the demand for gas throughout the day and also a considerable seasonal variation so that the maximum pressure is generally higher than the statutory minimum value.

Many of the gas distribution networks at present in operation, either due to their age or due to the materials of which they are constructed, are prone to leakage. Such leakage represents a serious financial loss to the supplier. It is therefore desirable, in order to minimise leakages, that supply pressures should at all times be maintained at the lowest possible values commensurate with safety and with the meeting of demands for gas. The invention has for its object to achieve this with relatively low power low cost apparatus.

According to the invention, there is provided gas supply pressure control apparatus including a pilot governor and electronic control means for

adjustments of said governor, said control means having means for storing a plurality of gas pressure time profiles and being arranged to act on the pilot governor in accordance with a selected one of said profiles, there being means for switching said control means to an alternative state for increasing the supply of gas as regulated by said pilot governor in response to a signal indicating an abnormally high demand for gas. Valve means for regulating said pilot governor may be arranged to be controlled by said electronic means, said valve means being connected to the gas supply. In this case, the valve means may comprise a higher pressure upstream valve connected to a higher pressure supply point and a downstream valve connected to a lower pressure point, said pilot valve being arranged to be alternatively exposed to the influence of the higher or the lower pressures. The upstream and downstream valves will preferably both be at least duplicated, the upstream valves being arranged in series and the downstream valves being arranged in parallel. Said valves will preferably be in the form of piezo-ceramic valves.

The electronic control means may be arranged to provide actuating outputs for the adjustment of the governor in a series of spaced pulses, the duration

of the pulses being varied according to an error signal represented by the difference between required and sensed pressures, and may be arranged to provide actuating outputs for the adjustment of the governor only when the downstream pressure strays outside a predetermined error band.

The electronic control means may be arranged to produce a predetermined change of supply conditions by determining the change of pressure per unit time effected by an initial actuating output and in accordance with the result so determined effecting a control function for the period of time required to produce said predetermined change.

A control chamber of the pilot governor regulated by said electronic control means may be provided with an external bleed such that in the absence of any supply of higher pressure gas by said regulation from the electronic control means the pilot valve tends towards a setting providing a higher pressure gas supply. Means will preferably be provided for adjusting the rate of flow of said bleed.

The gas supply pressure control apparatus may be in communication with a master station at which flow trends are displayed, the flow trends being

derived using historical data in the data-logger and gas supply pressure prevailing.

In order that the invention may be fully understood and readily carried into effect, the same will now be described, by way of example only, with reference to the accompanying drawings, of which:-

Figure 1 is a diagrammatic illustration of a gas pressure control system embodying the invention, for supplying gas to a district,

Figure 2 is a graphical record of pressures taken at different times to obtain a so-called pressure profile for a remote part of the district,

Figure 3 is a graphical illustration of how, within a gas main, the standard deviation of outlet pressure from the mean setting of a regulator has been found to vary according to flow,

Figure 4 is a graphical illustration of how control is applied to a pilot regulator in short pulses, and

Figure 5 is a graphical illustration of how the control is applied according to a so-called threshold concept,

Figure 6 is a further graphical illustration of how the control is applied,

Figure 7 is a diagrammatic illustration similar to Figure 1 but including a possible modification,

Figure 8 is a diagrammatic illustration of a detent device and associated control means for the modified arrangement of Figure 7, and

Figures 9 and 10 are diagrammatic illustrations which will be referred to when describing further possible modifications.

Referring to Figure 1 of the drawings, the pressure control system illustrated is a single input/single output system which includes a gas main 10 for a primary flow of gas and in which there are an active governor 14 and a monitor governor 16. An auxiliary pipe rail 12 is connected to the gas main at tapping points respectively upstream and downstream of the governors 14,16. In the auxiliary pipe rail are an auxiliary governor 26, and inspirator 20 connected to the active governor 14 to control its setting, an over-pressure governor 22 and a pilot governor 18. The monitor governor 16 and the over-pressure governor 22 are connected by respective lines 23,24 to the gas main downstream to be responsive to district pressure. The pilot governor 18 is regulated through an electronic control unit 28. The auxiliary governor 26 controls the pressure of gas

upstream of the inspirator 20 and also the pressure in pipeline 27 to the electronic control unit.

The electronic control unit 28 can conveniently comprise a data-logger such as are already known in the gas supply industry for obtaining records of gas supply to a district. In this instance, the functions of logger are expanded by additional software or a combination of software and hardware in order to regulate the control of the district supply pressure. The unit has connections through pipelines 13,15 for sensing the respective gas supply pressures upstream and downstream of the control system, as in a conventional data-logger. The unit is now also provided with control connections through the pipeline 27 from the auxiliary pipe rail 12 between the auxiliary governor 26 and the inspirator 20, the pipeline 11 to the district pressure end of the gas main 10, and the pipeline 29 to the auxiliary governor 18. A downstream pressure tapping from the pipeline 11 is also connected to the pilot governor 18.

The downstream or district pressure acts in the governor 18 against the normal spring bias of the governor to tend to restrict the flow through the governor as the district pressure increases. The pressure in the control pipeline 29 acts in a

second diaphragm chamber of the governor 18 in the same manner, ie. so that an increase of pressure in the pipeline 29 also tends to restrict the flow through the governor. Lowering the flow through the pilot governor 18 will also reduce the rate of flow through the inspirator 20 so that the active governor 14 closes, tending to restore the district pressure. Conversely, if the pressure at the downstream end of the main 10 falls below the pressure setting of the pilot governor 18, the latter opens further to increase the gas flow through the auxiliary pipe rail 12. This causes the active governor 14 to open further in response to the increased flow of gas through the inspirator 20. The pressure in the pipeline 29 is determined by a pair of gas valves 56,58 arranged in series between the pipelines 27,11, with the third pipeline joining the connecting line between the valves. The control pressure in the pipeline 29 is thus determined by the operation of the valves 56,58 in the following manner.

The governors 16,26 maintain the pressure in the pipeline 27 higher than the district pressure in the pipeline 10. The pressure in the pipeline 29 can be controlled between values determined by these two pressures through the operation of the

valves 56,58 since the pipeline 29 is connected to a closed volume represented by a diaphragm chamber of the governor. Thus, with the valve 56 held open and the valve 58 held closed, the pipeline 29 would be at the same pressure as the pipeline 27, while with the valve 56 held closed and the valve 58 held open it would be at the district pressure. In practice, the control pressure required will lie between these two extremes and will be produced by the valves 56 and 58 being opened and closed, selectively, for very brief periods of time to effect minute changes of pressure in pipeline 29.

The electronic control unit 28 comprises respective input sections 31,33 having pressure transducer means and analogue-digital conversion means for data inputs to a central processing unit (CPU) through interface 35. The control unit may perform the usual functions of a data-logger in storing data derived from the inputs 31,33 in a memory 54 to permit telemetric read-out of the data at intervals. In the present apparatus, the memory 54 also stores a number of required pressure-time profiles for the gas supply flow in the gas main 10 one such profile being indicated in Figure 2. The CPU is provided with means for comparing the data inputs from the sections 31,33 with the stored

pressure profiles to provide actuating outputs to the valves 56,58 through interface 37. In this way, predictable variations of gas demand can be anticipated and the downstream pressure can be maintained more uniformly while ensuring that gas at a suitable pressure reaches the furthest extremities of the district being supplied.

The predetermined pressure-time profiles held in the memory 54 will typically be derived from historical data. Such profiles may be downloaded into the memory for any desired period; a week might be suitable to allow for diurnal changes and week-end load patterns. Furthermore, while one profile may be sufficient to compensate for daily/weekly variations in gas demand, different profiles will generally also be required for use according to the time of the year, according to the prevailing weather conditions and to meet abnormal demands for gas. In order to be self-regulating, a plurality of different profiles can be stored in the memory to represent changes in seasonal conditions, eg. a winter profile, a summer profile and a spring/autumn profile. In an autonomous system such as this the switching of profiles can be triggered, for example by:

1) the changing seasons of the year,

11) ambient temperature variations,

111) analysis of transient pressure data.

The last technique will now be described further, by way of example, with reference to Figure 3 which is a diagrammatic illustration of the standard deviation of outlet pressure from a mean. It is found that the standard deviation varies according to the rate of gas flow, that is to say according to the instantaneous gas demand. Minimum deviation values occur at low rates of flow and maximum values at full flow. The CPU can be programmed to derive from a series of readings over a set period (eg. readings every 0.1 second over a 5 minute period) a standard deviation (o). Figure 3 illustrates a series of such standard deviation values plotted as $\pm$o with respect to the mean pressure. By integrating these values over a chosen time period it is possible to diagnose whether the flow through the governor is abnormal for the particular season and, if so, to switch to an appropriate different profile for a chosen period, eg. a day.

To avoid oscillations through feedback, the valve settings are preferably changed at intervals by pulsed signals as illustrated in Figure 4. The pulse width is preferably varied proportionately to

the error signal (the difference between required and actual pressures). Figure 4 also illustrates how the pulse width may be made proportional to the error signal represented by the difference between the required and sensed pressures. In addition, as illustrated diagrammatically in Figure 5, the control is applied only when the error exceeds a threshold of $\pm e$ in relation to the required pressure as represented by the line rp, so as to limit the power comsumption of the control system.

The actuation of the valves 56,58 can also be self-tuned by the technique illustrated in Figure 6. This illustrates how, in an initial test cycle, the control unit outputs a controlling signal to one or other of the valves for a brief period of time Et and measures the resultant change in pressure Ep from a starting pressure. The gradient Ep/Et is a first order approximation of the integral term used in the control loop in which the chosen valve 56 or 58 is operated and that gradient value is then used to determine the period of a longer control cycle. The gradient can then be recalculated if the pressure reached is not the desired pressure. This process may be reiterated if required and the gradient value eventually derived for each valve can then be employed to

determine the opening periods required for specific pressure corrections.

It has been found that the control apparatus described above can give an extremely close match between inferred and actual flow. It is thus possible to detect out of season peak loads under which conditions an alarm may be given and/or a change of pressure profile may be automatically brought into operation.

In order to protect against possible malfunction a number of further modifications may be made. In Figure 7, in which parts already described are indicated by the same reference numbers, a slam open valve 19 is provided in parallel with the pilot governor 18 to allow the governor to be bypassed. The valve 19 is normally held closed by control means as shown in Figure 8. The control means in Figure 8 comprises a detent device 30 which has a pin 32 one end of which engages a shoulder on a spindle 34 of the valve 19 to prevent the spindle from being lifted by a biasing spring to throw the valve 19 fully open. The pin 32 is secured to a diaphragm 36 which is acted on by an adjustable spring 38 and by the gas pressure in the chambers 40,42 on opposite sides of the diaphragm. The chamber 42 is connected to downstream pressure

by way of an adjustable needle valve 44 acting as a throttle and a pressure relief valve 46 in a conduit 48. The chamber 40 is connected directly to downstream pressure by way of conduit 50. The relief valve 46 is normally open but is set to close at a pressure equal to the acceptable minimum downstream pressure plus an equivalent pressure of the force of the spring 38.

In static conditions, the pressures in the chambers 40,42 are equal. However, if the downstream pressure should fall at a rate significantly greater than would occur through the operation of the electronic control unit, the throttling effect of the needle valve creates a differential pressure displacing the diaphragm 36 and so releasing the detent device 30. The primary control exercised by the pilot governor 18 will then be bypassed and the downstream pressure will be controlled by the pressure limiting governor 22, at a predetermined higher pressure than that set by the governor 18.

Alternatively, if the downstream pressure drops to a chosen minimum value, the relief valve 46 will close trapping the gas in the chamber 42 at that pressure. Any fall of pressure downstream will reduce still further the pressure in chamber 40

which will ultimately cause the release of the detent device 30, again resulting in the pilot governor 18 being bypassed and the higher pressure governor 22 being brought into operation.

Figure 8 also illustrates a receiver 49 in communication with the chamber 42. It holds an additional volume of gas to ensure that there is sufficient pressure gas to displace the diaphragm 36 when the detent device is to be released.

As a further safety measure, the valves 56,58 may be duplicated, as shown in Figure 9. The duplicated inlet valves 56 are placed in series to ensure that the path through them can be closed if either should fail. The duplicated exhaust valves 58 are placed in parallel to ensure their flow path can be opened if either should fail. If any one of the duplicated valves 56,58 should fail, therefore, the control of pilot governor 18 is maintained.

Figure 10 illustrates the provision of a pressure bleed-off from the pipeline 29 through which the pressure control of the valves 56,58 is exercised on the pilot governor 18. There is thus a direct flow line 60 between the pipeline 29 and the downstream end of the gas main 10 through a needle valve 62, which may be adjustable to determine the

flow rate. Under normal operating conditions loss of pressure because of the bleed flow will be compensated for by the inlet valve 56 occasionally opening. However, if the control system is unable to maintain pressure in this way, the lowering of the governor control pressure ensures that the governor drifts towards its high pressure setting and so avoids a so-called "fail-freeze" situation. Such a safety measure can guard against loss of power in the control unit. It can also be usefully employed in conjunction with the duplicated valve arrangement of Figure 9.

In the illustrated embodiments, the valves 56,58 can in general be any known type of electrically controlled gas valve, but piezo-ceramic valves are preferred for their low power consumption.

The gas pressure control apparatus described is able to maintain supply pressure at all times at the lowest possible values commensurate with safety and with meeting the demand for gas. Moreover, as there are other operational needs requiring the deployment of data-loggers at district governor stations the apparatus provides an economical way of achieving the logging and control functions within one instrument.

A further advantage of the control apparatus described is that it can be put in communication with a master station at which flow trends can then be displayed, the flow trends being derived using historical data in the data-logger and gas supply pressures prevailing.

CLAIMS:

1. Gas supply pressure control apparatus including a pilot governor and electronic control means for adjustment of said governor, said control means having means for storing a plurality of gas pressure time profiles and being arranged to act on the pilot governor in accordance with a selected one of said profiles, there being means for switching said control means to an alternative state for increasing the supply of gas as regulated by said pilot governor in response to a signal indicating an abnormally high demand for gas.

2. Gas supply pressure control apparatus according to claim 1, in which valve means for regulating said pilot governor are arranged to be controlled by said electronic means, said valve means being connected to the gas supply.

3. Gas supply pressure control apparatus according to claim 2, wherein the valve means comprise a higher pressure upstream valve connected to a higher pressure supply point and a downstream valve connected to a lower pressure supply point, said pilot valve being arranged to be alternatively

exposed to the influence of the higher or the lower pressures.

4. Gas supply pressure control apparatus according to claim 3, in which the upstream and downstream valves are both at least duplicated, the upstream valves beng arranged in series and the downstream valves being arranged in parallel.

5. Gas supply pressure control apparatus according to either one of claims 3 and 4, in which the valves are in the form of piezo-ceramic valves.

6. Gas supply pressure control apparatus according to any one of the preceding claims, in which the electronic control means is arranged to provide actuating outputs for the adjustment of the governor in a series of spaced pulses, the duration of the pulses being varied according to an error signal represented by the difference between required and sensed pressures.

7. Gas supply pressure control apparatus according to any one of the preceding claims, in which the electronic control means is arranged to

provide actuating outputs for the adjustment of the governor only when the downstream pressure strays outside a predetermined error band.

8. Gas supply pressure control apparatus according to any one of the preceding claims, wherein the electronic control means is arranged to produce a predetermined change of supply conditions by determining the change of pressure per unit time effected by an initial actuating output and in accordance with the result so determined effecting a control function for the period of time required to produce said predetermined change.

9. Gas supply pressure control apparatus according to any one of the preceding claims, in which a control chamber of the pilot governor regulated by said electronic control means is provided with an external bleed such that in the absence of any supply of higher pressure gas by said regulation from the electronic control means the pilot valve tends towards a setting providing a higher pressure gas supply.

10. Gas supply pressure control apparatus according to claim 9, wherein means are provided for adjusting the rate of flow of said bleed.

11. Gas supply pressure control apparatus according to any one of the preceding claims, in communication with a master station at which flow trends are displayed, the flow trends being derived using historical data in the data-logger and gas supply pressure prevailing.

12. Gas supply pressure control apparatus constructed, arranged and adapted to operate substantially as hereinbefore described with reference to and as illustrated by Figures 1 to 6 or Figures 7, 8, 9 or 10 of the accompanying drawings.

Patents Act 1977
Examiner's report to the Comptroller under Section 17 (The Search Report)

Application number
9201279.8

Relevant Technical fields

(i) UK Cl (Edition K) G3N NGB2A, NGB2, NGBX
G3R RBF, RBG29

(ii) Int CL (Edition 5) G05B 19/00, 19/02, 19/04
G05D 16/20

Search Examiner
P MARCHANT

Databases (see over)

(i) UK Patent Office

(ii) ONLINE DATABASE: WPI

Date of Search
29 APRIL 1992

Documents considered relevant following a search in respect of claims 1-12

Category (see over)	Identity of document and relevant passages	Relevant to claim(s)
X	US 4394871 (BOEING) See especially column 2 lines 32-36	1

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Category	Identity of document and relevant passages	Relevant to claim(s)

Categories of documents

X: Document indicating lack of novelty or of inventive step.

Y: Document indicating lack of inventive step if combined with one or more other documents of the same category.

A: Document indicating technological background and/or state of the art.

P: Document published on or after the declared priority date but before the filing date of the present application.

E: Patent document published on or after, but with priority date earlier than, the filing date of the present application.

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